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THIRD SEMI-ANNUAL REPORT
EVALUATION OF PHOSPHORIC ACID
MATRIX FUEL CELLS

INTERIM REPORT

by

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V. V. TANNA

AUGUST 1968

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Research & Development Procurement Office
U.S. Army Mobility Equipment Research and Development Center
Fort Belvoir, Virginia 22060

Contract No. DAAK02-67-C-0219
ENGELHARD
MINERALS & CHEMICALS CORPORATION
Research & Development
497 Delancy Street
Newark, New Jersey 07105

REF ID: A6479
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SUMMARY

The current evaluation studies under Contract No. DAAK02-67-C-0219 on air breathing phosphoric acid fuel cells have been concerned primarily with a detailed investigation of the most promising cell components available at the end of the preceding contract period.

The performance characteristics of cell units with these components are illustrated by the data given below.

	<u>125°C*</u>	<u>150°C**</u>
Initial Cell Voltage at 100 mA/cm ²	740 \pm 10 mV	760 \pm 10 mV
Degradation Rate in mV/100 hrs.	\leq 1 mV	\leq 2.5 mV
Demonstrated Life	>5000 hours	>3000 hours
Air Flow requirements for water balance at dew point 33°C	--	\leq 550 ml/Amp/min.

* Pure hydrogen

** Synthetic steam reformatte (74.6% H₂, 22% CO₂, 3% O₂, Balance CH₄)

At 150°C using synthetic steam reformatte as fuel a cell voltage of more than .70 volts could be maintained for 2000-2500 hours at 100 mA/cm². This is twice the life objective of the contract.

Degradation rates are substantially lower at 125°C than at 150°C. At the lower temperature, however, because of anode inhibition by carbon monoxide only pure hydrogen can be used as fuel -- at least if platinum black is employed as catalyst.

Neither air humidity nor air flow rates materially influence degradation rates provided the minimum requirements for water removal are satisfied. At the highest humidity level to be

expected in practice, the flow requirement for maintaining water balance is 550 ml/Amp/min. The cell performance is strongly dependent on the geometry of the current collector gas distribution structure. The limiting factor appears to be the necessity of making firm contact with the porous teflon electrode while permitting the removal of reaction water from the contact areas.

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1. INTRODUCTION

The objective of the current contract No. DAAK02-67-C-0219 has been to demonstrate a performance level of .70 volts at 100 mA/cm^2 after 1000 hours of operation for the air breathing matrix type phosphoric acid fuel cell developed by the Engelhard Minerals & Chemicals Corp. A catalyst loading of 12.5 mg/cm^2 of cell area was to be used and synthetic steam reformate containing 3% carbon monoxide was to serve as fuel.

These minimum objectives could be readily met already in the preceding contract period. The main factor was the development of a sufficiently stable and conductive matrix material which was accomplished in a company-sponsored effort. The best state of the art matrix cell initially delivers 70 watts/ ft^2 at .75 volts or 90 watts/ ft^2 at .70 volts. The catalyst cost based on performance after 1000 hours at 100 mA/cm^2 is of the order of \$650/KW.

To improve upon this performance the most promising approach appears to lie in an increase in power densities even at a sacrifice of cell efficiency. Fortunately, the matrix type phosphoric acid cell lends itself for high power density operation primarily because of the inherent simplicity of water and waste heat removal.

The problem to be solved is one of maintaining low degradation rates at high current densities. This may require operating temperatures below 150°C to decrease catalyst

recrystallization and the use of alloy catalysts on the anode to minimize carbon monoxide inhibition. Efforts in this direction should result in a reduction of the cost of materials in the future. Yet, even the performance level of the available cell units is sufficiently promising to warrant the development of multi-cell stacks and the investigation of temperature control and waste heat and water removal. Such an effort has now been underway for some time under Contract No. DAAK02-68-C-0407 with the objective of developing a stack to deliver 200 watts. With this stack development in progress, the evaluation studies on cell components have temporarily been oriented more towards providing essential design data on the state of the art cell unit rather than generation of data on newly developed materials. Of specific interest were the following points:

- 1) Reproducibility of initial cell performance and cell degradation rates.
- 2) Effect of air pressure, flow rate and humidity on degradation.
- 3) Effect of gasket and current collector materials on cell life.
- 4) Evaluation of advanced current collector structures.

2. EXPERIMENTAL

The evaluation and testing undertaken in this contract period was primarily concerned with a detailed study of the best available components rather than the evaluation of new materials. Thus mostly the matrix designated as 169 containing 60.5 wt.% phosphoric acid was used. The electrodes had a catalyst loading of 2.5 mg Pt black/cm² on the anode and 10 mg Pt black/cm² on the cathode. The cell size was 3.5 x 3.5 inches with an exposed area of 3 x 3 inches. As fuel pure hydrogen or steam reformate with 74.6% H₂, 22% CO₂, 3% carbon monoxide and .4% methane was employed. Per pass 75% of the hydrogen in the steam reformate was utilized. The air delivered to the cells was dried and purified over molecular sieve.

2.1 Facilities for Cell Evaluation

The test set-up has been shown previously in detail (1). Some changes have been made on the test rig in the current contract period in order to accomplish the following:

- 1) Decrease the back pressure on the air electrode.
- 2) Permit humidification of air.
- 3) Permit the evaluation of advanced current collector structures.

Air Back Pressure:

Prior to the present changes the valves and tubing downstream of the test cell caused an air back-pressure of several inches of water at the flow rates commonly used. In order to reduce this pressure the air is now directly vented through a

series of holes in the end plates into the heated chamber. With precious metal screens as current collectors the back pressure on the cathode decreased to about 1.5 inches of water and to less than .1 inch of water on some experimental current collector structures.

Current Collectors:

The testing of advanced current collectors has been taken up in this contract period. The structures tested consist of ribbed base metal plates as depicted in Figure 1. Plates with open areas of 50, 60 and 75% were evaluated.

For testing the current collector is inserted into a recess on the stainless steel end plates. It is planned to do most of the future testing with these structures as more data becomes available of their suitability.

Air Humidification:

An air humidification system was built to investigate the humidity effect on degradation rates. The set-up consists of an electrically heated humidification chamber, a water reservoir and stripper to prevent any spray from reaching the test cell.

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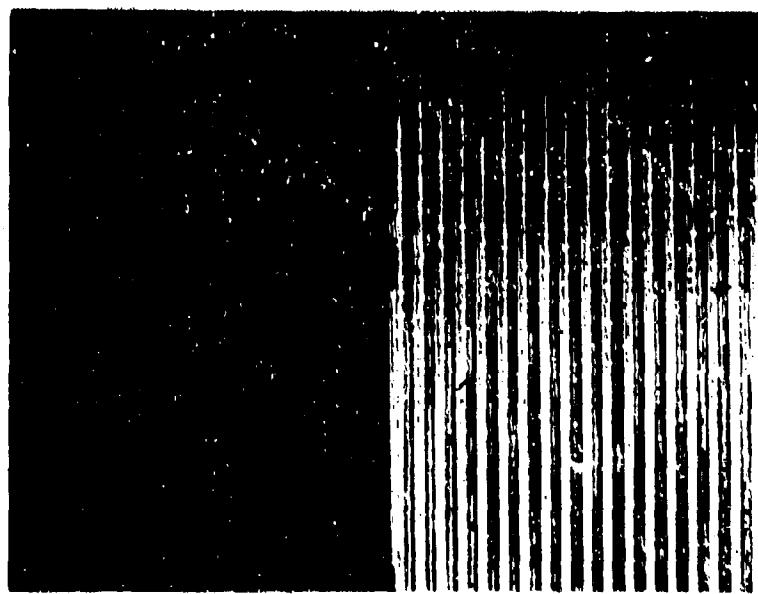


Figure 1

Current Collector and Gas Distribution
Structures for Air Breathing Phosphoric
Acid Fuel Cells

2.2 Endurance Testing and Evaluation of Cell Components

All testing in this contract period was done at constant current densities of 100 mA/cm² or 140 mA/cm² and temperatures of 125°C and 140-150°C. Most tests were limited to less than 1000 hours although some of the endurance tests were carried on in excess of 2,000 hours.

2.2.1 Testing of Gas Distribution and Current Collector Structures

Until recently the evaluation of cell units was accomplished exclusively in rigs in which pads of precious metal screens served both for the purpose of gas distribution and current collection. The resiliency of such pads has been a major factor in obtaining uniform electrical contact even making up for variation in the cell thickness. This is of particular importance with the metallized teflon electrodes because of their relatively low conductivity.

We now have undertaken to replace these screens with protected base metal structures such as depicted in Figure 1. The problem in using these collectors is to develop structures which are compatible with the characteristics of the porous teflon electrode. The problem has been the rigidity of the collector plates and the difficulty of making and maintaining contact without excessive deformation of the electrode and matrix and obstruction of the electrode process.

Two types of assemblies are being investigated with these rigid structures. In the first case, the stainless steel endplates with the collector inserts are pressed against spacer gaskets which maintain the gap between the endplates at 37 mils. Alternatively a spring loaded arrangement is used and a constant pressure of 700 psig is applied onto the 3.5 x 3.5 inch cells. The latter arrangement was used in most of the preliminary investigation. The following collector patterns were evaluated:

	<u>Groove Width</u>	<u>Rib Width</u>	<u>Groove Depth</u>
A.	30 mils	30 mils	60 mils
B.	30 mils	20 mils	30 mils
C.	30 mils	7-10 mils	30 mils

With collector A the initial cell performance was significantly below that obtained with screens. An examination of the cells indicated an accumulation of acid on the electrode at the areas of contact. This was taken to indicate that transport of water from these areas was a limiting factor. Pattern B with narrower ribs showed a current-potential behavior almost identical with screen collectors. Surprisingly, pattern C with even more open area appears to be inferior to B. A more detailed evaluation of these and similar structures is underway and will be discussed in the next report. At present one life test with pattern B has been terminated after 2,000 hours of testing. It is discussed in section 2.2.4.

2.2.2 Reproducibility of Cell Performance

While the contract objectives of a cell performance of better than .70 volts after 1,000 hours at 100 mA/cm² have been met with some of the cell units towards the end of the last contract period, the reproducibility of performance with the best components remained to be established. The reproducibility could now be demonstrated by the runs 5190, 5191 and 5215 (Tables 1, 1-1 and 1-2).

The initial voltage variation at 100 mA/cm² is less than ± 10 mV and the decay rate is almost identical, namely 2.3 mV/100 hours. Together, less than half of the degradation appears to result from an increase in matrix resistance and a decay of the fuel electrode (Tables 1-1, 1-2).

A cell life in excess of 2,000 hours is obtained to a cut-off voltage of .70 volts. There is some evidence for an increase in the degradation rate after 2,500 hours, at least with impure hydrogen (Figure 2).

At a current density of 140 mA/cm² a substantially faster decay is encountered than at 100 mA/cm². This is evident from run 5181 (Table 2). With impure hydrogen as fuel the decay rate is 5.8 mV/100 hours.

2.2.3 Effect of Cell Temperature on Degradation Rates

Since catalyst recrystallization is a predominant factor in cell decay (2), a decrease in cell temperature should improve performance stability particularly at higher current densities.

TABLE 1

Summary of Life Tests of
Air Breathing Cells With Various Matrix Materials

Fuel: 74.5% H₂, 22% CO₂, 3% CO, .4% CH₄
Current Density: 100 m A/cm²

Anode: 2.5 mg Pt/cm²
Cathode: 10 mg Pt/cm²

Run	Matrix	Temp. °C	Initial	Hours				(Cell Voltage in mV)	Discontinued	Discontinued	Discontinued
				200	400	600	800				
5176*	Preparative Variation of 169	144-147	746	716							
5177	Preparative Variation of 167	145-6	734	663							
5216*	Preparative Variation of 169	143-6	775	770	764	757	752	747	745	Discontinued	
5190	169	142-6	767	758	753	748	742	732	731	730	Discont'd.
5215	169	143-6	764	760	754	750	742	740	738	732	Discontinued
5197*	171	145-8	793	761	759	752	746	742	<740	Discontinued	
		Thickness 40 mils.									
5199	172	143-6	758	742	731	718	713	700	696	Discontinued	
5191	169	145-51	767	758	752	748	742	735	732	720	722

* Test runs with pure hydrogen

TABLE 1-1
Open Circuit Cell Resistance in mΩ

Run	Matrix	Temp. °C.	Initial	200	400	Hours 600	800	1000	1200	1400	1600	1800	2000
5176	Preparative Variation of 169	144-47	6.0	7.5	Discontinued								
5177	Preparative Variation of 169	145-6	10.8	12.6	Discontinued								
5216	Preparative Variation of 169	143-6	3.5	3.4	3.5	4.0	4.0	4.0	4.0	4.0	4.2	Discontinued	
5215	169	143-6	7.2	7.5	8.6	-	8.0	7.6	8.0	8.0	8.5	Discontinued	
5197	171 Thickness 40 mils	145-8	6.9	7.5	7.8	7.5	7.2	7.1	-	Discontinued			
5199	172	143-6	3.6	3.6	3.9	3.2	4.0	4.5	4.7	Discontinued			
5191	169	145-51	3.6	4.2	4.5	4.8	5.0	4.8	4.9	5.3	5.0	5.3	5.3

TABLE 1-2
 Performance Difference Between Pure and Impure Hydrogen (mV)
 (Current Density 100 mA/cm²)

Run	Matrix	Temp. °C	Initial	200	400	600	800	1000	1200	1400	1600	1800	2000
5176	Preparative Variation of 169	144-47	30	54	(Voltage difference in mV) Discontinued								
5177	Preparative Variation of 169	145-5	28	51	Discontinued								
5215	169	143-6	16	15	18	14	20	18	23	23	Discontinued		
5199	172	143-6	14	28	34	38	42	52	55	Discontinued			
5191	169	145-51	23	15	15	14	16	17	15	18	18	15	22

FIGURE 2

LIFE TEST WITH AIR-BREATHING CELL AT 125°C. & 150°C.

ANODE: 2.5 mg Pt/cm²
CATHODE: 10 mg Pt/cm²
CURRENT DENSITY: 100 mA/cm²

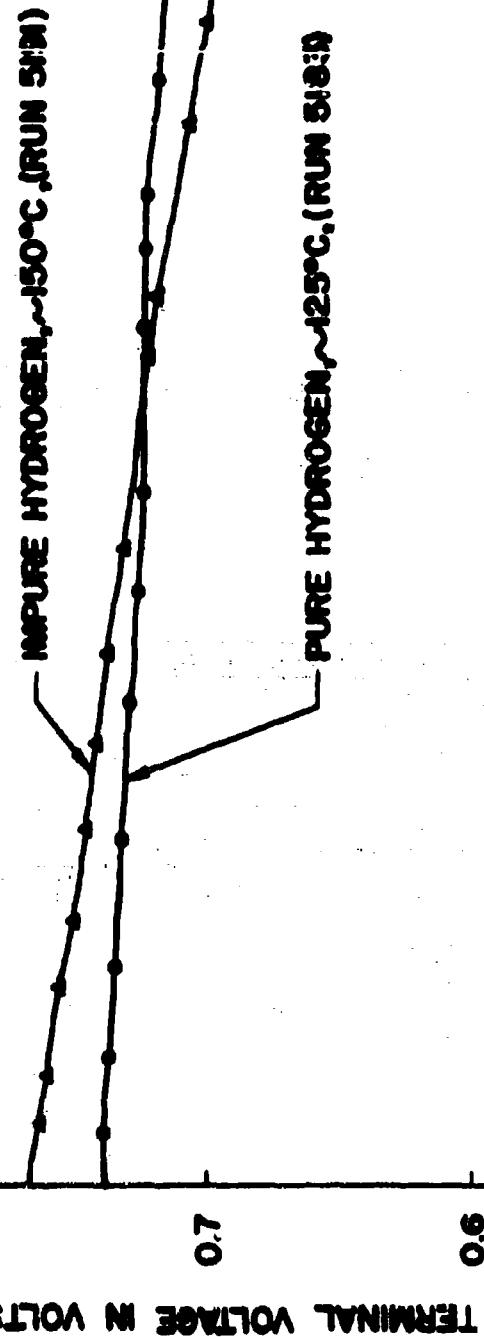


TABLE 2

Summary of Life Tests of
Air Breathing Cell with Various Matrix Materials

Fuel: 74.6% H₂, 22% CO₂, 2% CO, .4% CH₄
 Current Density: 140 mA/cm²
 Anode: 2.5 mg Pt/cm²
 Cathode: 10 mg Pt/cm²

Run	Matrix	Temp. °C	Initial 100	200	300	400	500	Hours 600	700	800	900	1000	1100	1200
5143	**	144-8	730	719	708	696	685	(Cell Voltage in mV)						
5145*	**	145	750	732	720	707	685	Discontinued						
5146	**	145-6	721	-	703	670	648	Discontinued						
5181	169	144-5	744	736	732	724	719	710	703	695	688	687	683	681
5164*	169	122-5	690	692	685	681	674	672	671	666	667	667	665	667
5149	**	145-6	723	714	706	692	689	680	678	675	670	665	Discontinued	

* Test runs with pure hydrogen

** Preparative variations of matrix 169

Unfortunately, with platinum black as catalyst on the fuel electrode, the sensitivity towards inhibition by carbon monoxide increases markedly as the temperature is decreased below 150°C. The possibility exists, however, to overcome this problem by the use of alloy catalysts. Before taking up testing with alloyed catalysts we have carried out two tests to establish the degradation rates at lower temperatures. By using pure hydrogen as fuel an indication could be obtained at least of the stability of the air electrode and the electrolyte matrix under the milder conditions.

The respective runs are 5183 at 100 mA/cm² (Figure 2) and run 5164 at 140 mA/cm² both at 125°C (Table 2). The first run which is still continuing shows a degradation rate of .8 mV/100 hours as compared to 2.3 mV/100 hours for a comparable run, for instance 5191, at 150°C. Admittedly, in the latter run impure rather than pure hydrogen was used as fuel which may have slightly accelerated the decay.

The second test at 125°C which was run at 140 mA/cm² showed initially a fairly fast decay which after 500 hours slowed down to a rate of approximately 1 mV/100 hours. This test (Run 5181) was carried on for a total of 5,000 hours with an overall degradation rate of 2 mV/100 hours. Between 1000 hours and 3000 hours degradation is about 1 mV/100 hours but the rate accelerates after that time. Both tests demonstrate that decay is significantly lower at 125°C than at 150°C particularly at higher current densities.

2.2.4 Effect of Humidity on Cell Degradation Rates

Up to now the cell testing was carried out with air of low humidity content. The dew point in the early part of the test program has been about 10°C and presently with the installation of a molecular sieve drier it is -40°C . Obviously the water content of the air admitted to the cell may effect both the water balance, the performance level as well as the degradation rate. An endurance test was set up to investigate the humidity effect over extended periods of time at a saturation level and temperature to simulate the worst conditions to be encountered in practice. Since the water transport from the electrode to the air stream may be a problem under these conditions, we used a rigid ribbed current collector designated as B (page 7) rather than a screen collector which due to its particular contact pattern may give results more favorable than obtainable with other patterns.

The cell was first operated at a flow rate of 180 ml/Amp/min. At this level the voltage was found to fluctuate 20-30 mV at a current density of 100 mA/cm^2 . This was thought to be an indication of partial electrode drowning. Consequently the flow was increased and at 550 ml/Amp/min. a stable output was obtained. The test was then carried on for a period of about 2000 hours. The data are summarized in Table 3. There is no apparent effect of the humidity on performance provided the minimum air flow required for water removal is maintained. Degradation in 2000 hours was 45 mV or about 2.3 mV/100 hours, the same as observed with dry air. Equally comparable to tests with dry

TABLE 3

Summary of Life Test with Humidified Air

Run 5209

Fuel: 74.6% H₂, 22% CO₂, 4% CH₄Current Density: 100 mA/cm², Temperature 149-153°CAnode: 2.5 mg Pt/cm², Cathode: 10 mg Pt/cm², Matrix 169.

Current Collector: Protected Aluminum, 60% open area

Air Flow: 550 ml/Amp/min., Dew point ~30°C

Hours	Initial	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	Disc-	cont.
Cell Voltage in mV	755	-	-	746	740	735	730	729	715	711	710	710		
Difference between pure & impure hydrogen in mV	19	-	-	14	13	12	12	11	11	12	14	18		
Cell resistance at open circuit in mΩ	4.0	3.8	3.8	4.1	4.8	4.3	4.3	4.4	4.4	4.6	4.9	-		

inlet air is the matrix stability and the difference between pure and impure hydrogen.

2.2.5 Evaluation of New Matrix Materials

Only a small number of new matrix materials were evaluated in this contract period. Among the matrices investigated were those with the composition of matrix 169 which, however, with the aim of simplifying fabrication techniques were prepared by a variety of new methods. The evaluation results obtained at 100 mA/cm² are shown in Tables 1-1 and 1-2 (Runs 5176, 5177 and 5216) and for 140 mA/cm² in Table 2 (Runs 5143, 5145, 5146 and 5149).

There is a surprisingly wide variation in performance noticeable for the same matrix composition depending on the preparative method used. This is presumably related with its effect on the continuity of the pore structure.

Runs 5176 and 5177 have very high degradation rates particularly with impure hydrogen and so do all runs at 140 mA/cm². Also the cell resistance does increase markedly faster than with the standard 169 matrix.

The matrix tested in run 5216 shows a degradation rate comparable to the standard 169 matrix both in respect to voltage decay and resistance increase. This material, which was not tested with impure hydrogen in the initial evaluation, will be subjected to further testing. Two totally new materials were tested in runs 5197 and 5199. The matrix materials are

designated as 171 and 172 (Table 1). Both materials gave encouraging results and warrant further investigation. Of particular interest is matrix 171 because of its excellent stability (Table 1-1).

2.2.6 Effect of Teflon Content in Catalyst Layer on Electrode Life

The electrodes employed in the evaluation studies under this contract are wet proofed by the addition of 20-25 wt.% teflon to the catalyst layer. Little information is available on the effect of variations of this teflon content in particular in respect to cell life. Such a study was undertaken using matrix 169 and teflon concentrations of 15, 30 and 40 wt.%. Pertinent data appear in Tables 4, 4-1 and 4-2. Except for the lowest teflon concentration, the initial performance is not significantly affected by the teflon concentration. Cell degradation, however, differs markedly and is lowest at a level of 20-25% teflon. With 15 wt.% teflon the degradation is particularly fast. In this case, judging from the increase in cell resistance (Table 4-1) and the accelerated decay with impure hydrogen (Table 4-2), the problem is progressive electrode drowning. Less obvious is the cause for the faster decay at 30 wt.% and 40 wt.% teflon. It could be associated with increased I.R. losses in the catalyst layer and reduced availability of the platinum surface.

TABLE 4

Effect of Teflon Content on Electrode Life

Fuel: 74.6 H₂, 22% CO₂, 3% CO, 0.4% CH₄
 Current Density: 100 mA/cm²
 Anode: 2.5 mg Pt/cm²

Run	Teflon Content in Weight %	Temp. °C	Initial	100	200	300	400	500	600	700	800	900	1000		
														Hours	(Cell Voltage in mV) Discontinued
5159*	15	142-5	721	-	689	672	660	645							
5191	20-25	145-51	767	764	758	755	752	752	748	745	742	738	735		
5173	30	142-5	770	762	758	753	749	746	742	737	735	732	728		
5174	40	145-7	767	758	749	736	732	728							

* Current Density 140 mA/cm²

TABLE 4-1
Open Circuit Cell Resistance in m Ω

Run	Teflon Content Wt. %	Temp. °C	Initial	100	200	300	400	Hours	500	600	700	300	900	1000
(Cell Resistance in m Ω)														
5159	15	142-5	5.4	6.2	6.4	7.4	8.0	8.9	Discontinued					
5191	20-25	145-51	3.6	3.9	4.2	4.2	4.5	4.5	4.6	4.2	5.0	4.7	4.8	
5173	30	142-5	3.5	3.5	4.0	4.0	4.1	4.1	4.2	5.1	5.1	5.1	5.1	
5174	40	145-7	4.2	4.9	5.1	5.5	5.8	-	Discontinued					

TABLE 4-2

Performance Difference Between Pure and Impure Hydrogen (mV)

Run	Teflon Content Wt. %	Temp. °C	Initial	100	200	300	400	Hours 500	600	700	800	900	1000	(Voltage difference in mV)	
														25	25
5159	15	142-5	18	18	21	-	-	15	15	14	14	14	16	17	17
5191	20-25	145-51	23	-	15	15	15	15	15	14	14	14	16	17	17
5173	30	142-5	17	20	20	22	22	24	24	23	23	24	26	29	34
5174	40	145-7	17	19	20	20	20	18	-	-	-	-	-	-	-

2.2.7 Effect of Materials of Cell Construction on Performance

We have noticed on certain occasions in the stack development work under Contract No. DAAK02-68-C-0407 a rapid decline in performance which could not be explained on the basis of data available from single cell testing with 3.5 x 3.5 inch cells.

Possible poisoning effects were suspected from various materials used in the cell construction. The effect of these materials was systematically evaluated in a number of single cell experiments. Pertinent data are summarized in Tables 5, 5-1 and 5-2. They show the effect of copper and nickel additions to the matrix and give an indication of the compatibility of the rubber materials used as a gasket. Copper has a very detrimental effect on cell performance particularly when impure hydrogen is used as fuel. The effect of nickel is less severe. This is attributed to some residual curing agent, a peroxide compound, (DiCup R) which inhibits the anodic reaction particularly when carbon monoxide is present in the fuel. Fortunately, this compound can be removed by vacuum treatment as shown in tests 5213 and 5194.

TABLE 5

The Effect of Copper, Nickel and Gasket
Materials on Cell Degradation Rates

Fuel: 74.6% H₂, 22% CO₂, 3% CO, .4% CH₄
Current Density: 100 mA/cm²
Matrix: 169

Run	Purpose of Test	Mode of Testing	Temp. °C	Initial	Test Duration in Days							
					1	2	3	4	5	6	7	
5188	Study effect of copper	Addition of 50 mg copper powder to matrix	140-9	777	780	765	738	704	Cathode: 10 mg Pt/cm ² Anode: 2.5 mg Pt/cm ² Discontinued			
5192	Study effect of nickel	Addition of 50 mg nickel powder to matrix	145	727	744	-	745	-	745	-	736	-
5187	Compatibility of rubber gasket as received	Gasket was used on anode	142-6	764	-	747	735	723	Discontinued			
5213	Compatibility of rubber gasket	Heated in vacuum at 100°C and soaked in KOH	149	772	-	772	-	765	-	-	-	757
5194	Compatibility of rubber gasket	Same as with run 5213. Gasket was protected however with 1 mil teflon foil.	149-50	750	-	751	750	-	-	742	-	740
												735

TABLE 5-1

Open Circuit Resistance in mΩ

Run	Temperature	Initial	1	2	3	Test Duration in Days	(Cell Resistance in mΩ)			10
							4	5	6	
5188	140-9	11.4	12.0	16.5	18.0	18.6				
5192	145	6.6	-	-	6.9	-	7.6	-	7.8	-
5187	142-6	-	6.6	5.8	5.1	5.4	Discontinued			-
5213	149	6.3	-	6.3	-	5.5	-	-	-	5.8
5194	149-50	4.8	-	4.8	4.8	-	-	4.8	-	5.1
										-
										5.4

TABLE 5-2
 Performance Difference Between
Pure and Impure Hydrogen
 (Current Density 100 mA/cm²)

Run	Temp. °C	Initial	Test Duration in Days													
			1	2	3	4	5	6	7	8	9	10				
			(Voltage difference in mV)													
5188	140-9	19	10	-	44	36	Discontinued									
5192	145	18	-	-	18	-	17	-	18	-	20	19				
5187	142-6	24	24	40	50	57	Discontinued									
5213	149	23	15	-	13	-	16	-	-	-	-	15				
5194	149-50	-	-	19	19	23	23	23	-	-	24	-				

CONCLUSIONS

The evaluation studies of the past contract period have been useful in defining more clearly the conditions required for optimum cell operation. Data have been accumulated on the effect of temperature, air humidity, pressure or flow rate on cell degradation. Also the relationship between the geometry of current collector-gas distribution structures and performance has been studied.

As to be expected, degradation rates decrease substantially with a decrease in cell temperature particularly at higher current densities. This undoubtedly is related with the rate of catalyst recrystallization. Air humidity and flow rate - provided water balance is maintained - fortunately do not appear to affect the degradation pattern. There is some indication, however, of a slight acceleration of decay if a pressure differential exists between anode and cathode. This may be related to a shift in the electrode-electrolyte interphase.

The geometry of current collector-gas distribution structures may significantly influence performance. The problem is one of maintaining uniform contact of rigid structures with the electrode while still providing short enough a diffusion path at the contact areas to remove the reaction water. With the porous teflon electrode this condition appears to be satisfied with ribbed structures having a 30-mil groove and 20-mil rib width.

FUTURE WORK

We intend to undertake in the forthcoming contract period investigations aimed at defining the conditions most favorable for cell operation at current densities substantially above 100 mA/cm².

These investigations will entail the evaluation of optimized matrix materials and electrode structures and in particular the study of alloy catalyst which may permit a reduction of the anodic polarization. A full cell evaluation of such catalysts will be preceded by screening tests in half cells. Full cell testing will be done at current densities of 150-200 mA/cm², temperatures below 150°C and impure hydrogen as fuel.

We intend to employ in the course of this evaluation work to an increasing extent current collector-gas distribution structures and cell assembly conditions commensurate with the stack development in progress under Contract No. DAAK02-68-C-0407.

LITERATURE REFERENCES

1. Evaluation of Phosphoric Acid Matrix Fuel Cells,
Engelhard Industries, Inc., Contract DAAK02-67-C-0219,
First Semi-Annual Report, Pages 8-13.
2. Ibid., Second Semi-Annual Report, Page 5.

Unclassified

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Engelhard Minerals & Chemicals Corp. Research & Development Department Newark, New Jersey		2a. REPORT SECURITY CLASSIFICATION Unclassified
2. REPORT TITLE Evaluation of Phosphoric Acid Matrix Fuel Cells		
3. DESCRIPTIVE NOTES (Type of report and inclusive dates) Third Semi-Annual Report Feb. 18, 1968 - August 18, 1968		
4. AUTHOR(S) (Last name, first name, middle) Adlhart, O. J. Tanna, V. V.		
5. REPORT DATE August 1968	7a. TOTAL NO. OF PAGES 28	7d. NO. OF REPS 2
6a. CONTRACT OR GRANT NO. DAAK02-67-C-0219	6a. ORIGINATOR'S REPORT NUMBER(S)	
6b. PROJECT NO. 6c. 6d.	6b. CIMER REPORT NO(S) (Any other numbers that may be assigned to report)	
10. AVAILABILITY/LIMITATION NOTICES This document is subject to special report controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of Commanding Officer, US Army Mobility Equipment Research & Development Center, Fort Belvoir, Virginia 22060.		
11. SUPPLEMENTARY NOTES An evaluation of air breathing phosphoric acid matrix fuel cell units is carried out. Cells are life tested with synthetic steam reformatte at about 150°C. Initially, 70 watts/ft. ² is obtained at .75 volts and 90 watts/ft. ² at .70 volts using a platinum loading on anode and cathode combined of 12.5 mg/cm ² . At a temperature of 150°C and a current density of 100 mA/cm ² cells decay at the rate of 2.5 mV/100 hours. Degradation is substantially lower at 125°C. Neither air humidity nor air flow rates materially influence degradation rates provided the minimum requirements for water removal are satisfied. At the highest humidity level to be expected in practice, the flow requirement for maintaining water balance is 550 ml/Amp/min.	12. SPONSORING MILITARY ACTIVITY U.S. Army Mobility Equipment Research and Development Center Fort Belvoir, Virginia 22060	
13. APPROXIMATE		

DD FORM 1 JAN 64 1473

Unclassified
Security Classification